Resource assessment and siting using SRTM 3 arc-second elevation data

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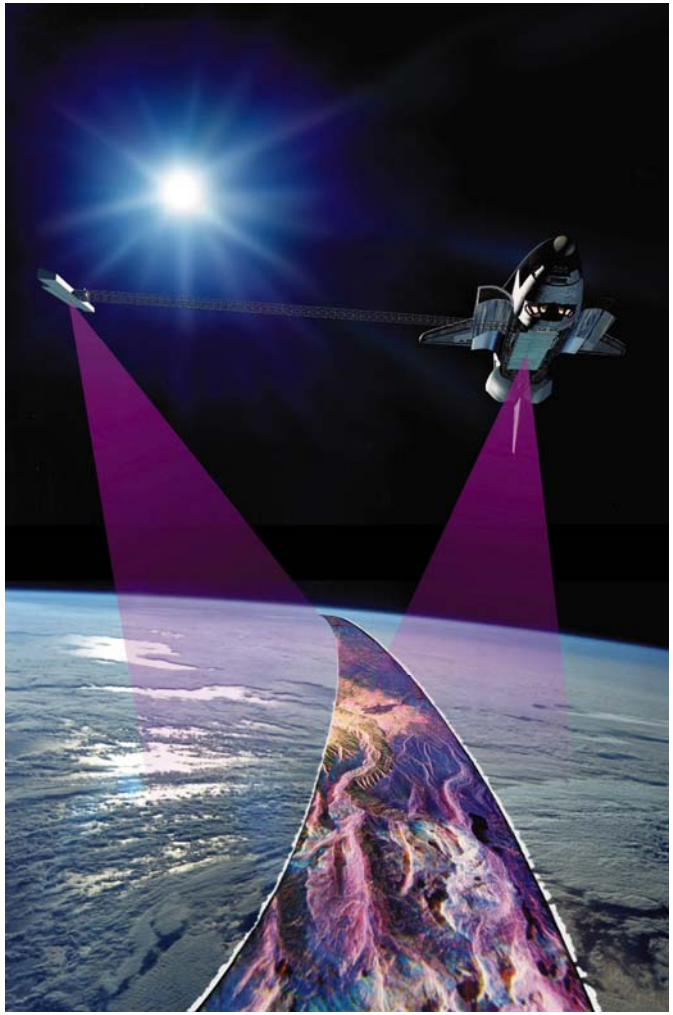
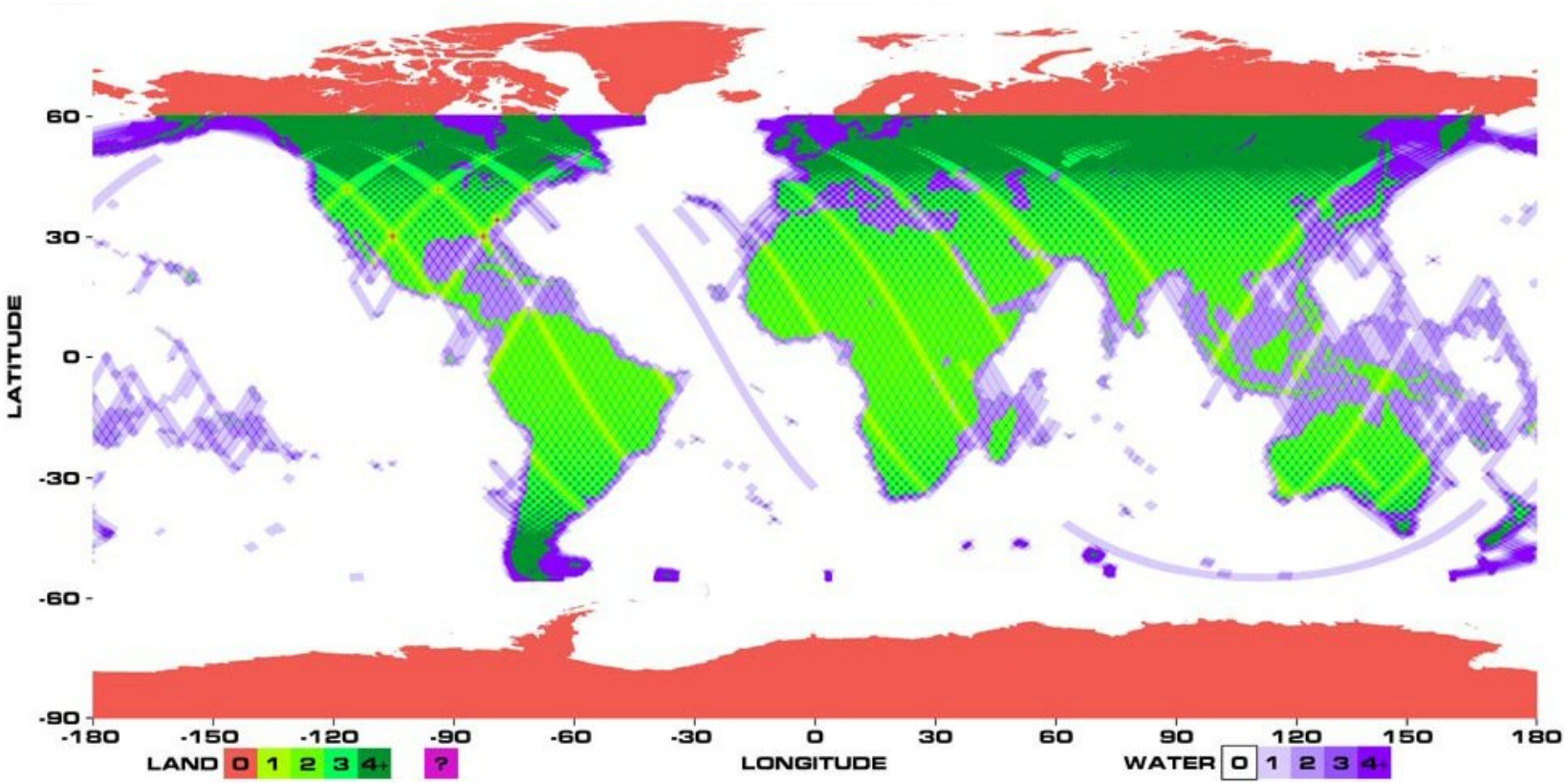
Shuttle Radar Topography Mission (SRTM)



- Space Shuttle February 2000
- Radar interferometry technique
- 80% of the Earth's land mass
- 9 terabytes of raw data
- Grid point elevations
  - 1 arc-sec (~30 m) for USA
  - 3 arc-sec (~90 m) outside
- Vertical accuracy 5-10 m
- Unedited and finished data
- Digital Surface Model rather than Digital Elevation Model

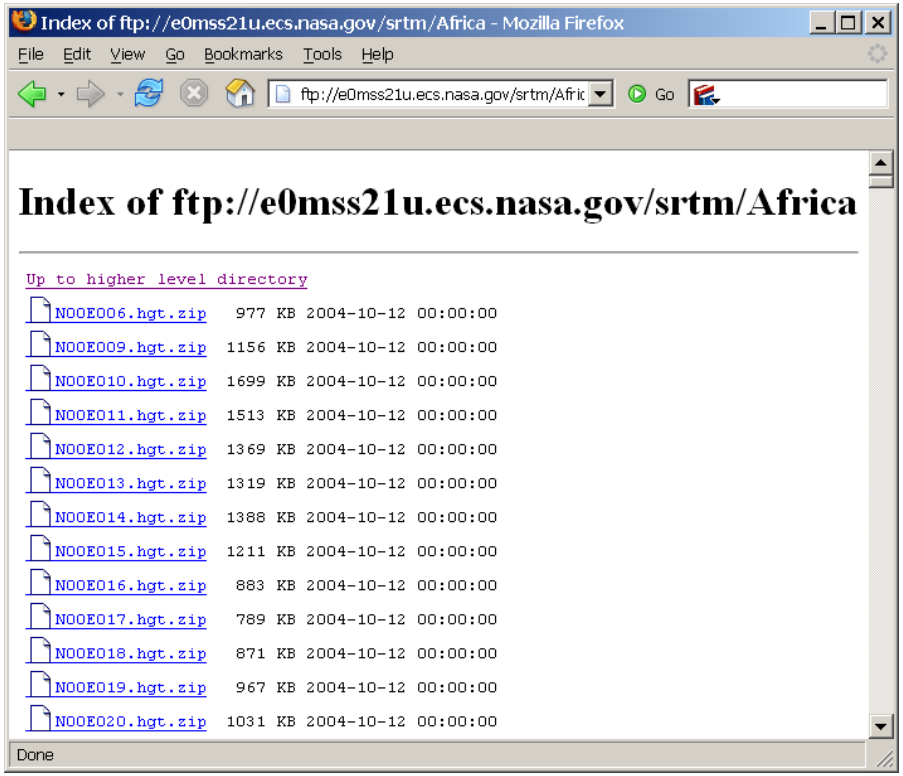
- For more information, visit http://www2.jpl.nasa.gov/srtm/

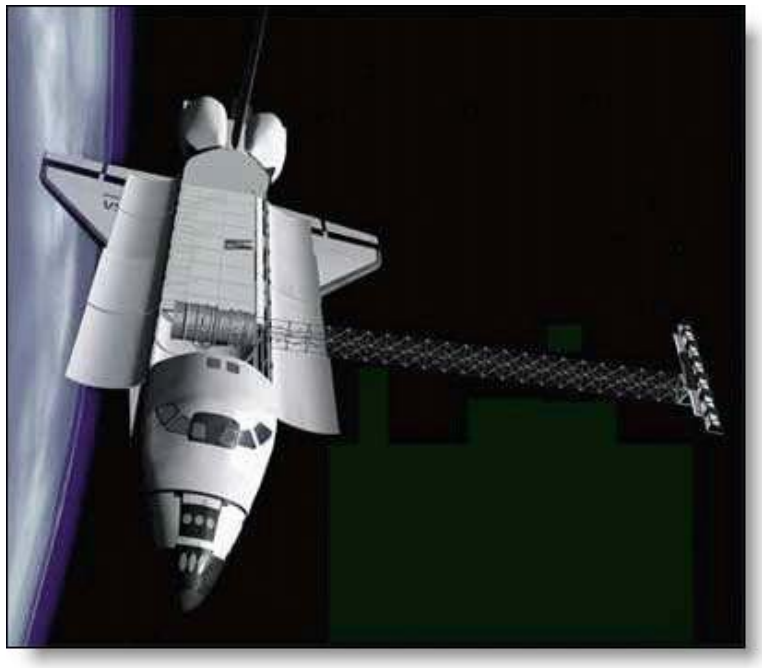
SRTM coverage map



- Colour indicates number of passes by space shuttle

SRTM data from ftp site (research grade)





- File name refers to lower left (LL) corner of 1×1 degree tile
- HGT format similar to the GTOPO30 format supported by Surfer

Transforming SRTM data to WAsP maps

- SRTM coordinates are non-projected (latitude, longitude)
- Horizontal reference system is WGS84
- Vertical reference is the EGM96 geoid

- Transforming SRTM data to WAsP maps therefore require:
  - Transformation of geo. coordinates to metric system
    WAsP Utility Programs, WAsP Map Editor, …
  - Transformation of WGS84 to another datum – if need be
    WAsP Map Editor, WAsP Utility Programs, …
  - Transformation of grid point elevations to height contours
    Surfer 8, GIS, WAsP Utility Programs, …

One possible procedure is outlined in the following…

Converting SRTM HGT file to GRD format

- To convert from HGT to GRD using Surfer 8:
  - Unzip the downloaded ZIP file
  - Rename the HGT file to DEM
  - Create HDR and STX files (with the same file name)
  - Insert upper left corner coordinates (signed) in the HDR file
  - Start Surfer and choose Grid | Convert…
  - Open *.HDR file
  - Save grid as *.GRD file

✓ Result: Surfer GRD file in geographical coordinates (WGS84)

Formats of HDR and STX files

HDR file (3 arc-sec/90 m)

```
BYTEORDER M
LAYOUT BIL
NROWS 1201
NCOLS 1201
NBANDS 1
NBITS 16
BANDROWBYTES 2402
TOTALROWBYTES 2402
BANDGAPBYTES 0
NODATA -32768
ULXMAP 32.000000000000
ULYMAP 30.000000000000
XDIM 0.000833333333333
YDIM 0.000833333333333
```

Upper left corner *X*-coordinate

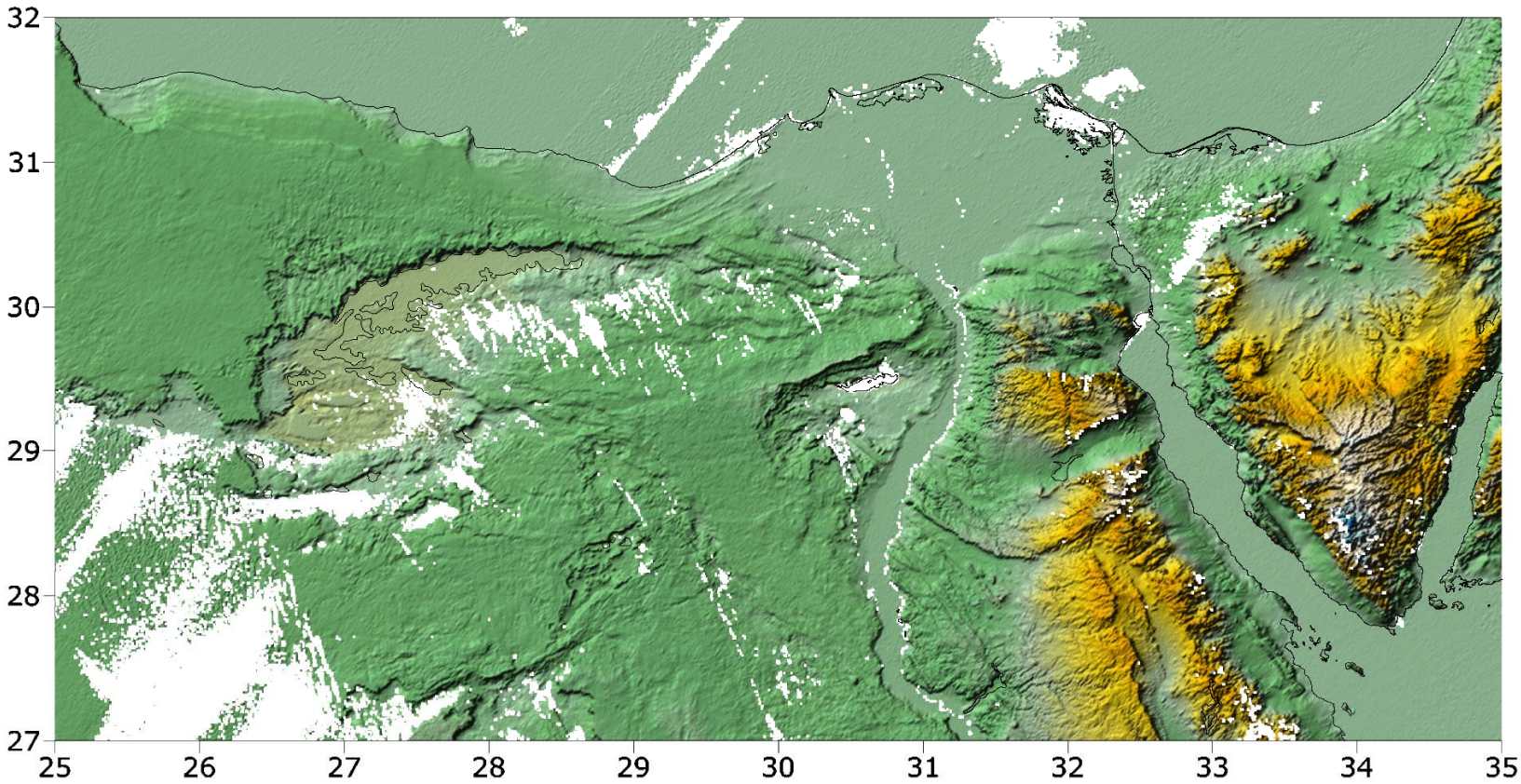
Upper left corner *Y*-coordinate
- remember signed coordinates!

STX file (one line text file)

```
1 0 1000 500 100
```

The STX file (statistics) consists of a “1”, followed by the minimum, maximum, mean, and standard deviation of the *Z* values.

Inspection of raw SRTM data



- Check for missing information (voids = white)

Changing coordinate system to UTM

- First, convert grid file to list-of-points file
  - In Surfer, choose Grid | Convert…
  - Open GRD file and save as ASCII XYZ (*.dat)
- Second, transform geographical to UTM coordinates
  - In WAsP Utility Programs window, write UTM 1
  - Enter the UTM zone number
  - Drag and drop DAT file from Windows Explorer to the CPI
  - Write ‘y’ to ‘File of (X, Y, Z) coordinates’
  - Drag and drop the DAT file again; change extension to *.xyz

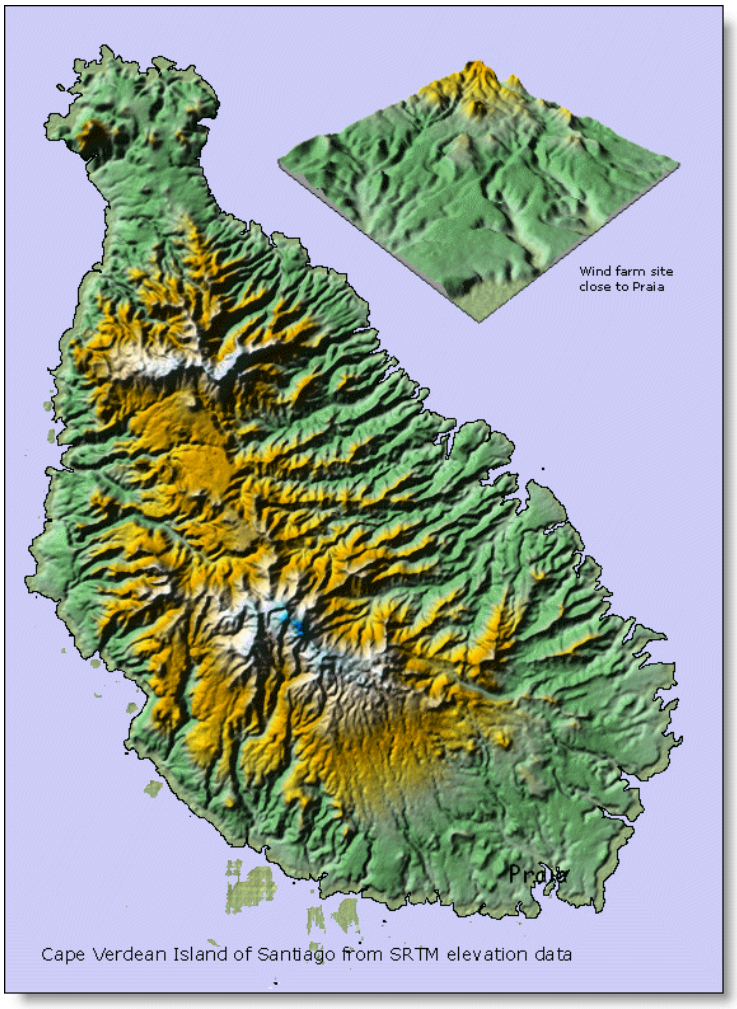
✓ Result: ASCII XYZ file in metric map coordinates (WGS84)

Making a metric GRD file

- In Surfer, choose Grid | Data…
  - Open the XYZ file as ‘Golden Software Data’
  - Choose ‘Skip leading spaces’
  - Choose ‘Treat consecutive delimiters as one’
  - Choose name for ‘Output Grid File’
  - Choose values for ‘Grid Line Geometry’
    - Grid size and extents of modelling domain

✓ Result: Surfer GRD file in metric map coordinates (WGS84)
  - Complete grid without voids (hopefully)
  - Spikes and wells may still occur

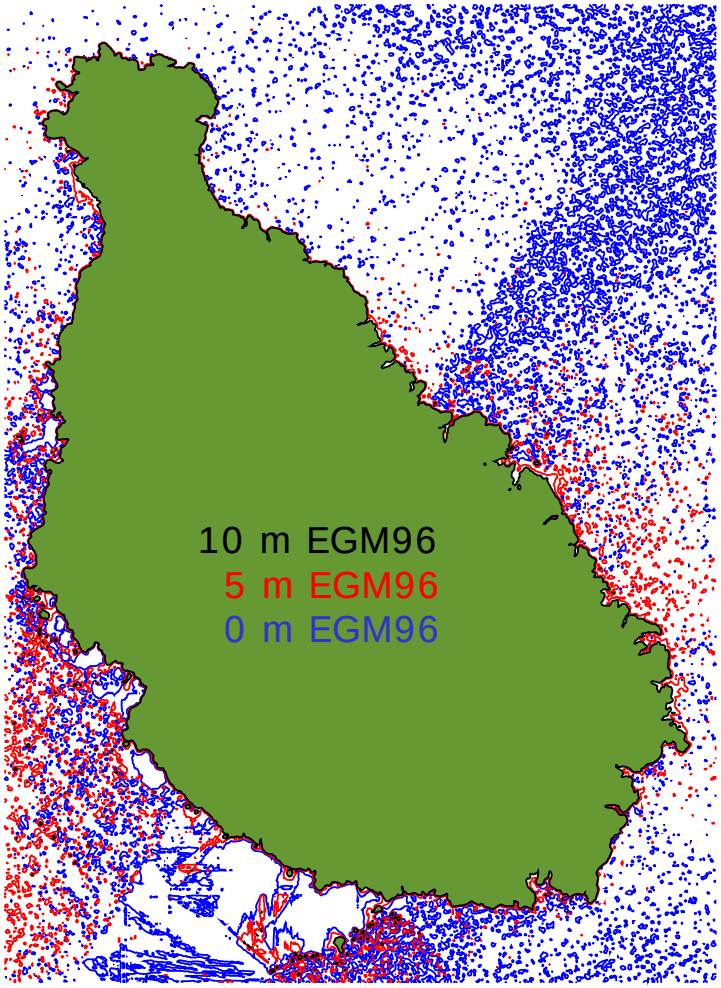
Surface plot of terrain elevation



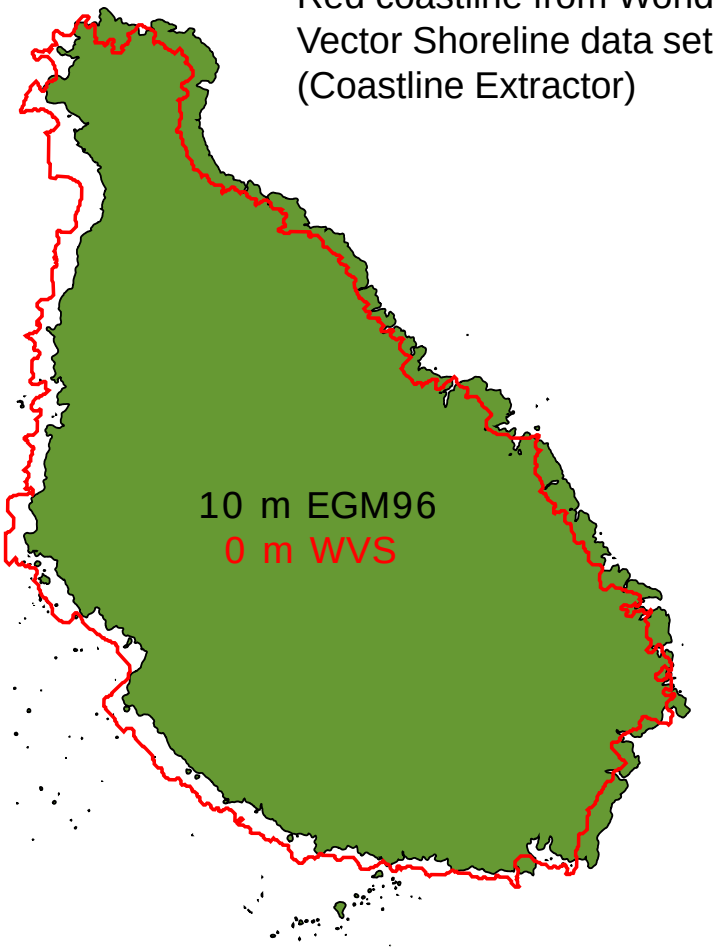
- Santiago, Cape Verde
  - Area: 55 × 40 km^2
  - 1101 rows × 801 columns
  - $\Delta x = \Delta y = 50$ m
  - Elevations from 0 to 1335 m

- Wind farm site
  - Area: 10 x 10 km^2
  - 1001 rows x 1001 columns
  - $\Delta x = \Delta y = 10$ m
  - Elevations from 0 to 480 m
  - View from SE towards NW
  - Elevation angle = 30°
  - Vertical exaggeration ~3x

SRTM coastlines…



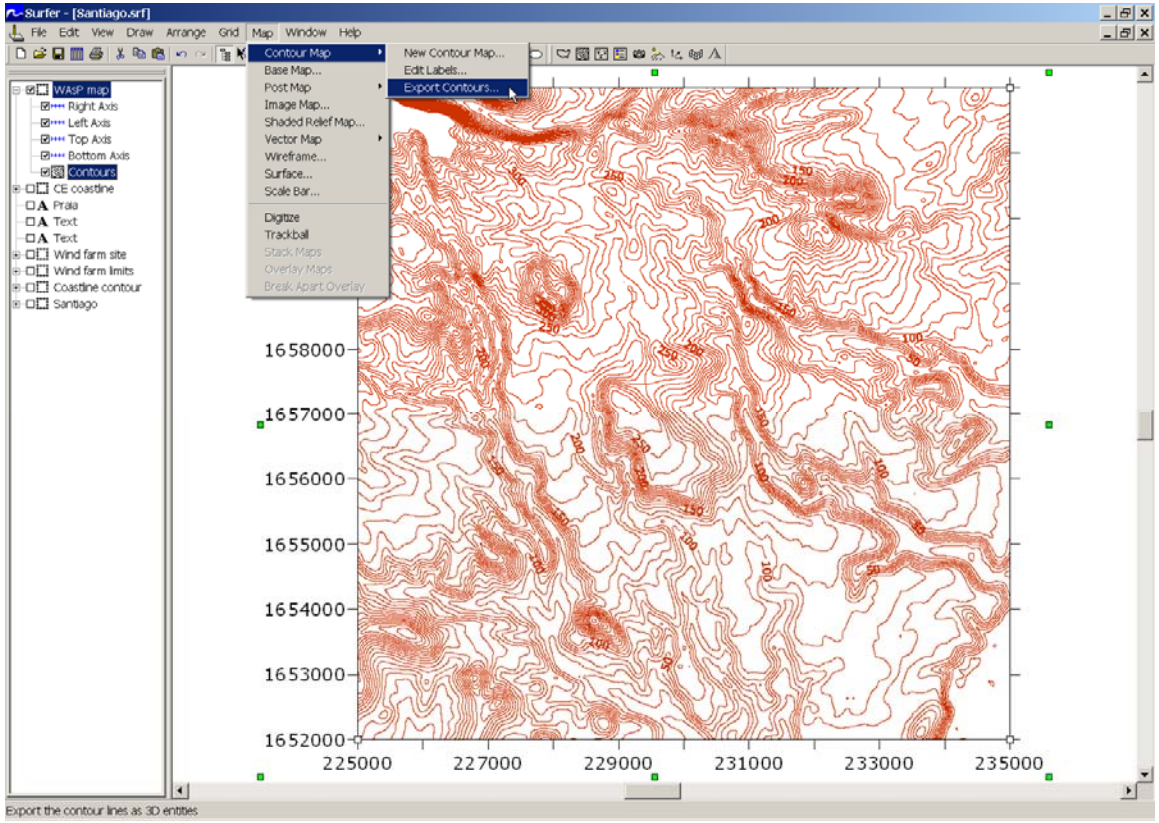
Red coastline from World Vector Shoreline data set (Coastline Extractor)



Making a contour map in DXF format

- Create a new contour map in Surfer, using the GRD file as input
- Export the height contours to 3-D AutoCAD DXF file

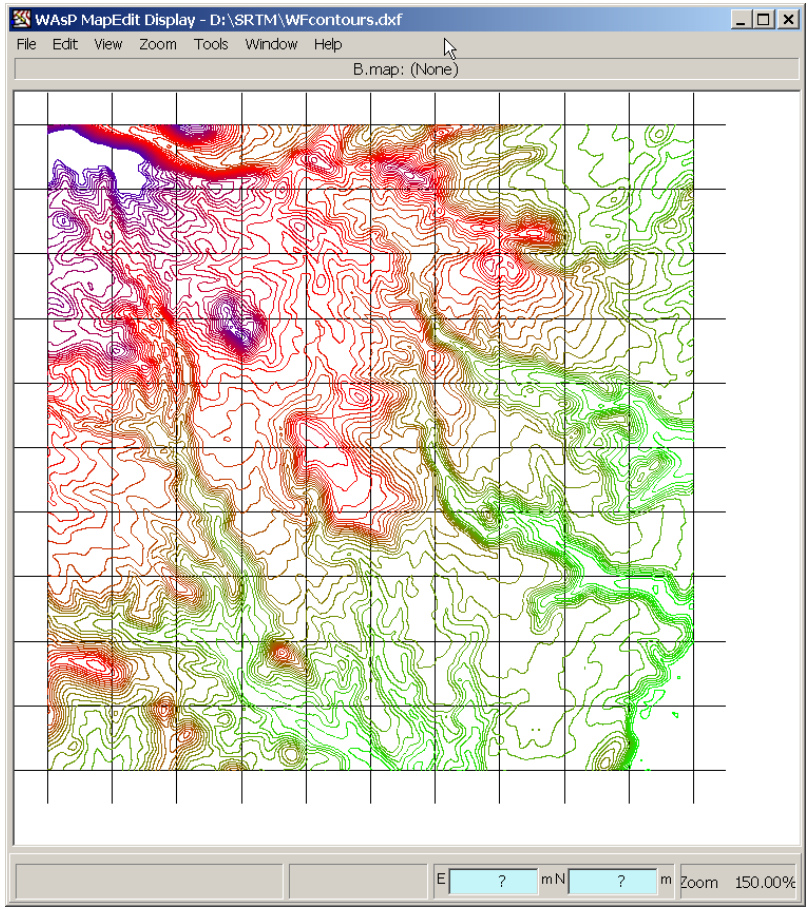
Tip: choose appropriate contour levels



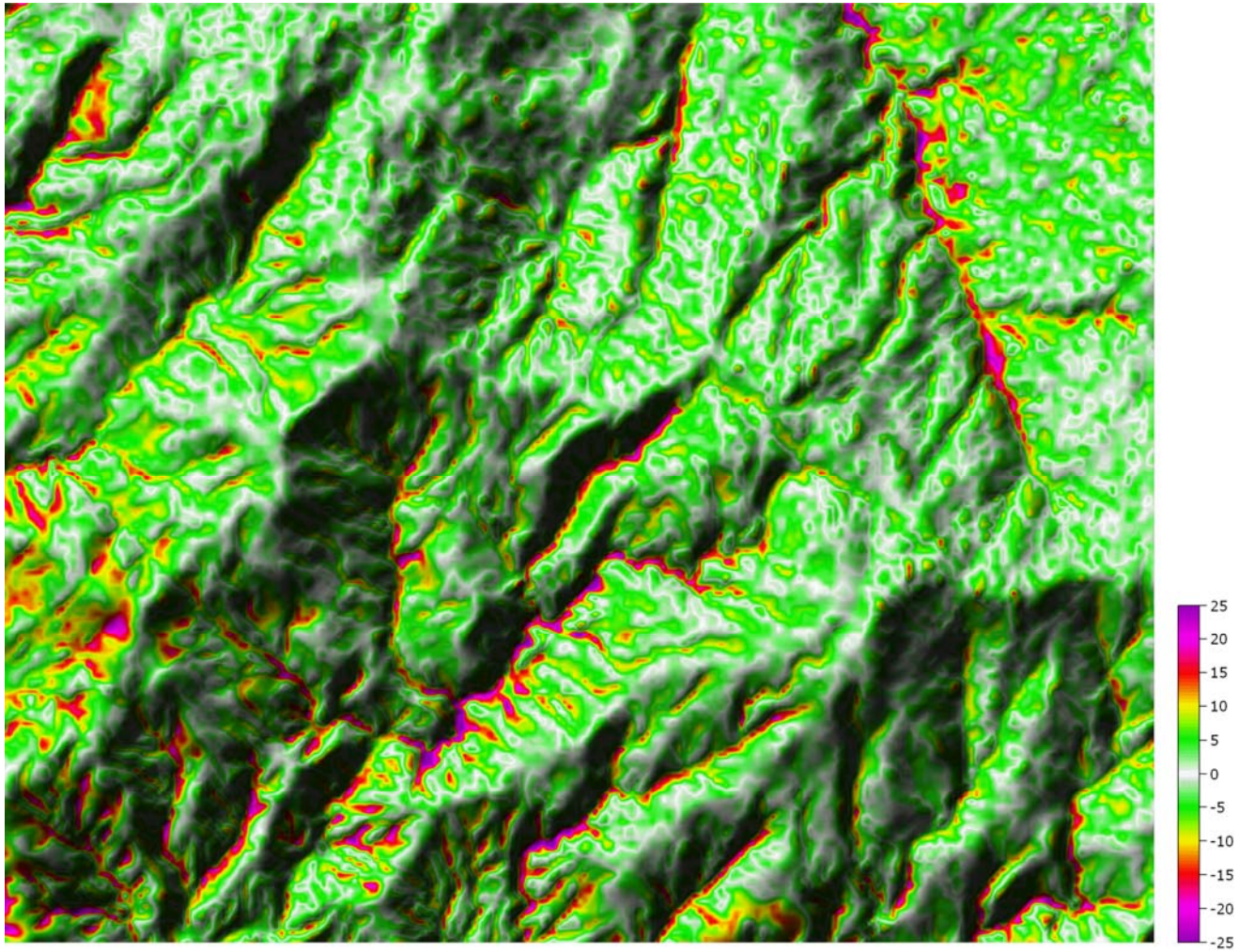
Making a WAsP contour map

- Open DXF map in the WAsP Map Editor
- Check the map contours for spikes and wells
- Transform to any other datum
- Compare to background map
- Add details close to the site(s)
  - Check vertical datum
- Add roughness change lines
- Save the map as WAsP ASCII map file (*.map)

✓ Mission accomplished!



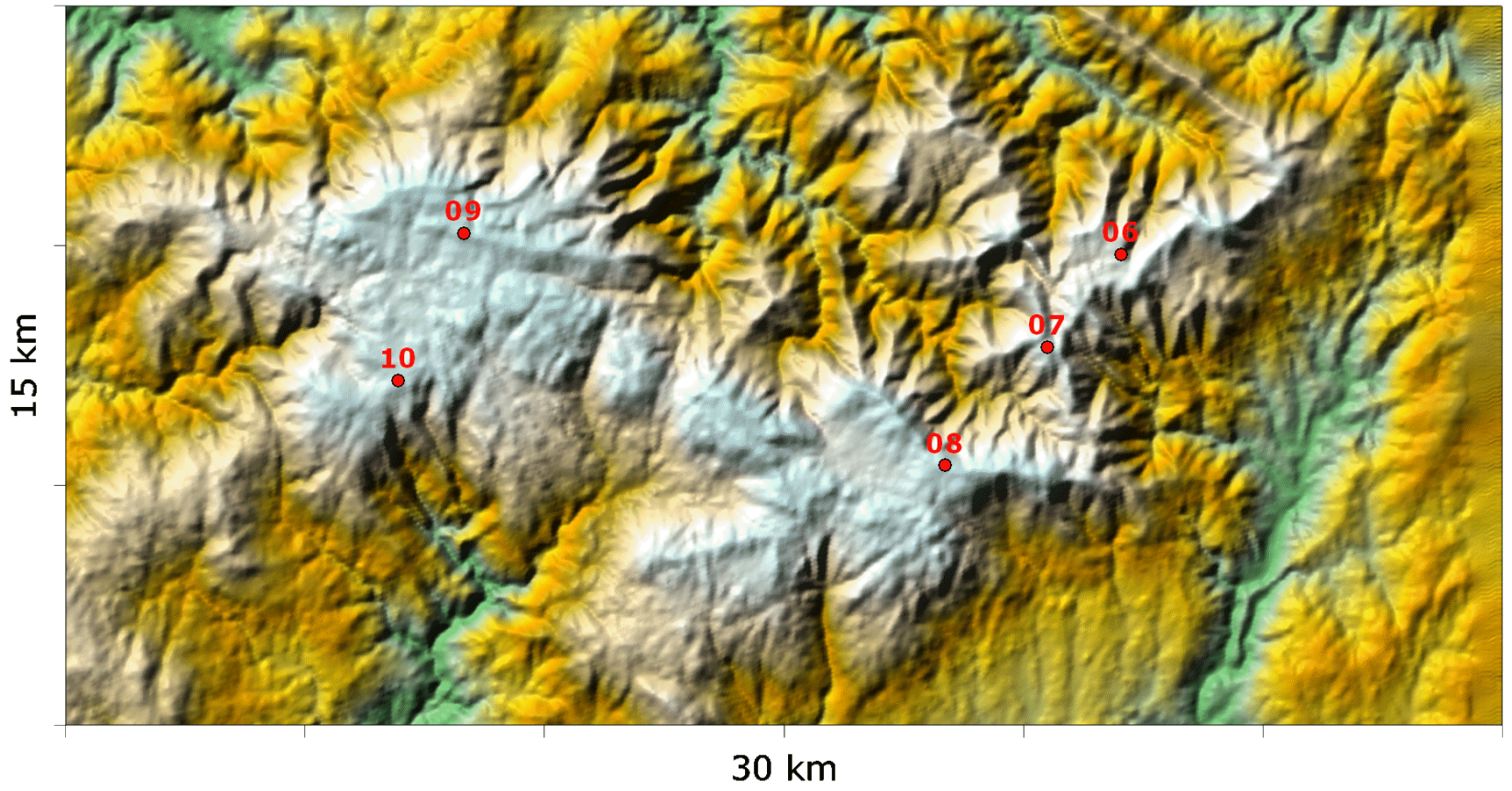
Comparison of SRTM and reference maps



- Reference z is from DXF map by IGeoE
- Unedited SRTM processed like described above
- Spacing of grid points is 100 m
- Difference Δ is calculated as $\Delta = z - z_{ref}$ for each grid point
  - $\langle \Delta \rangle$ = 2.5 m
  - σ_Δ = 5.7 m

Δ-scale in [m]

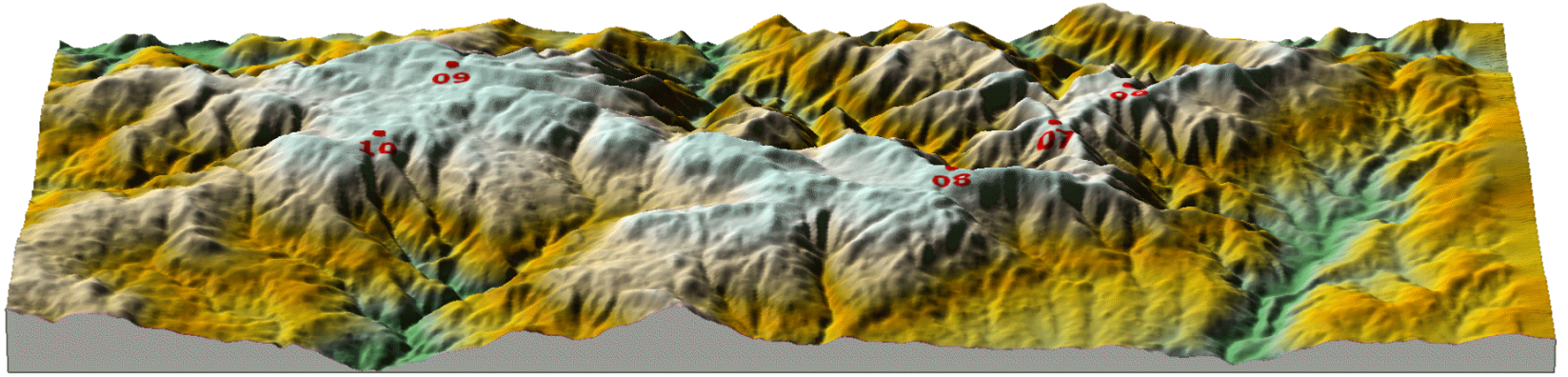
Case study in northern Portugal



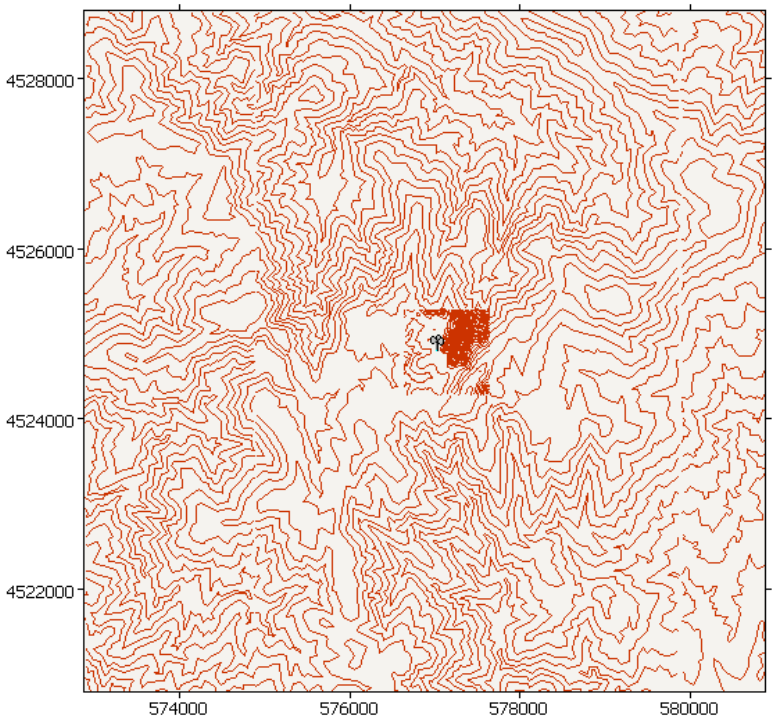
- Five sites in complex terrain (height scale exaggerated ×2)

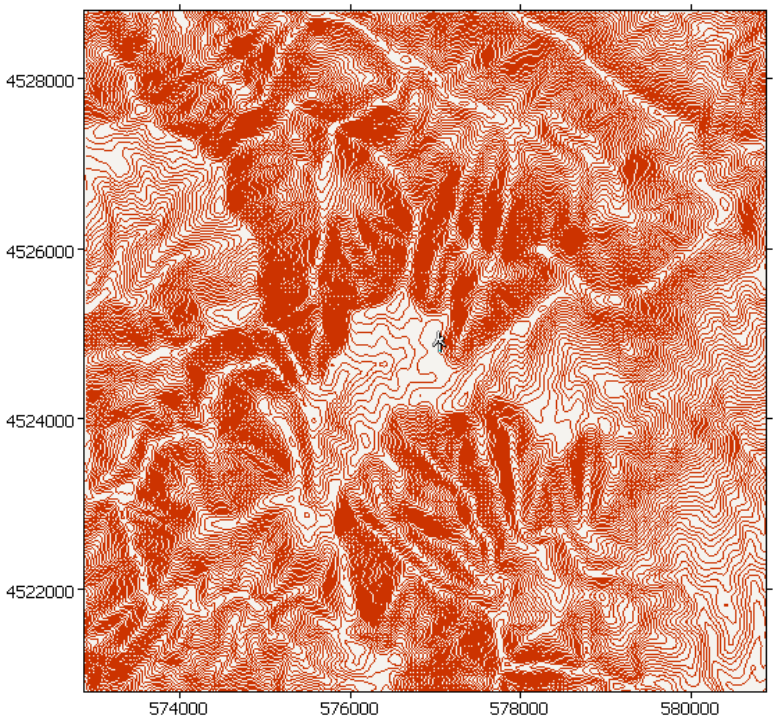
Site characteristics

	Hand-digitised map		SRTM map		10-m wind
Station	Elevation [m a.s.l.]	RIX [%]	Elevation [m a.s.l.]	RIX [%]	U_{10} [m/s]
Port 06	933	25	930	28	4.49
Port 07	982	29	980	33	5.16
Port 08	1047	17	1040	18	6.06
Port 09	1082	9	1070	10	5.84
Port 10	1012	9	1010	11	5.56



Map characteristics

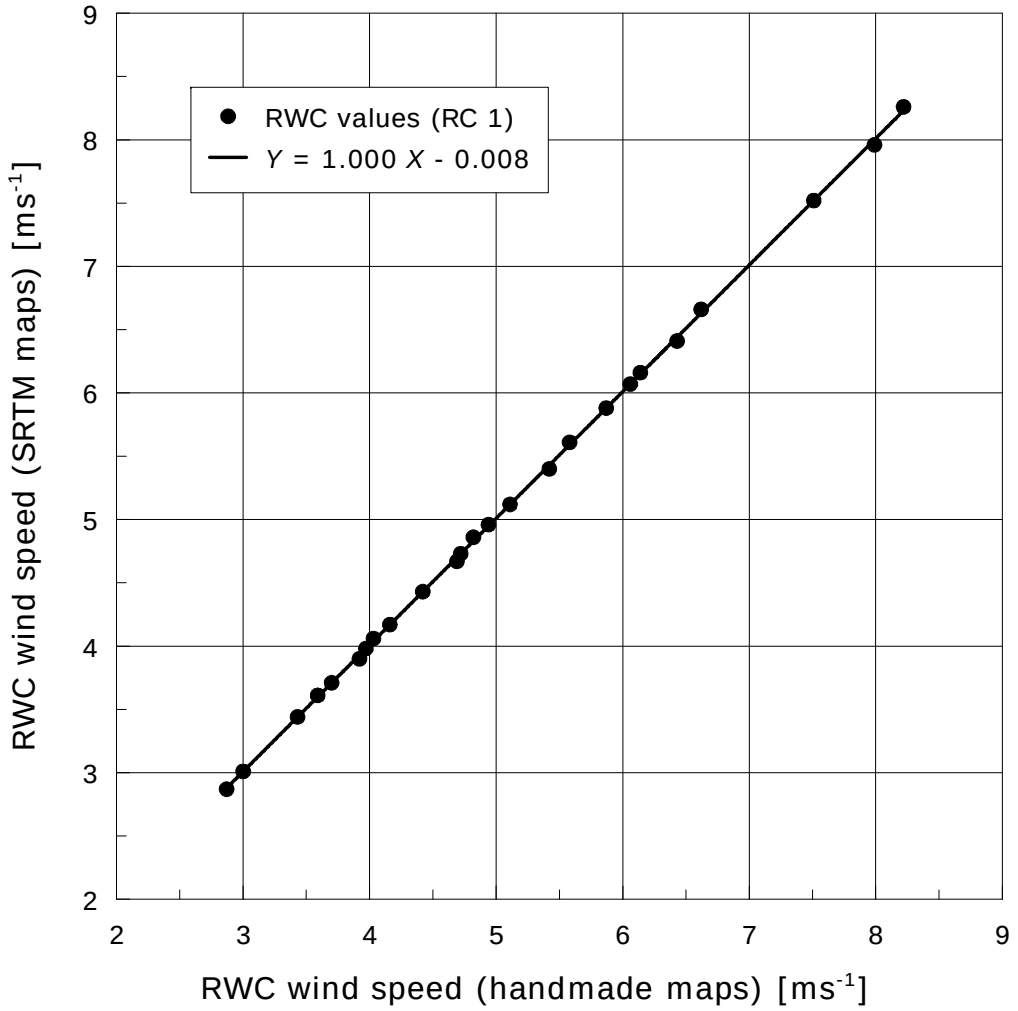




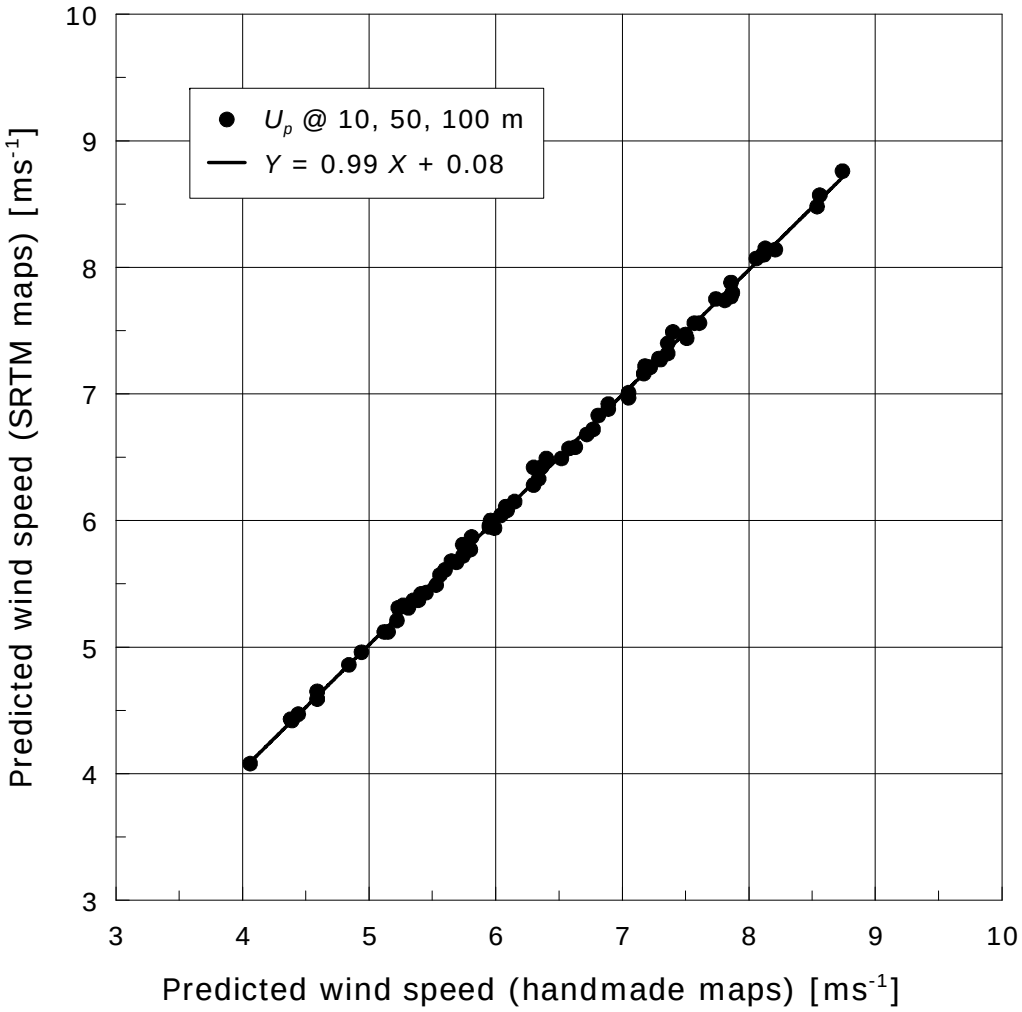
- Hand-digitised from 1:25,000 maps
- 50- and 10-m height contours
- Spot elevations

- Contoured from SRTM data (Surfer)
- 10-m height contours all over…
- Spot elevation (mast only) added

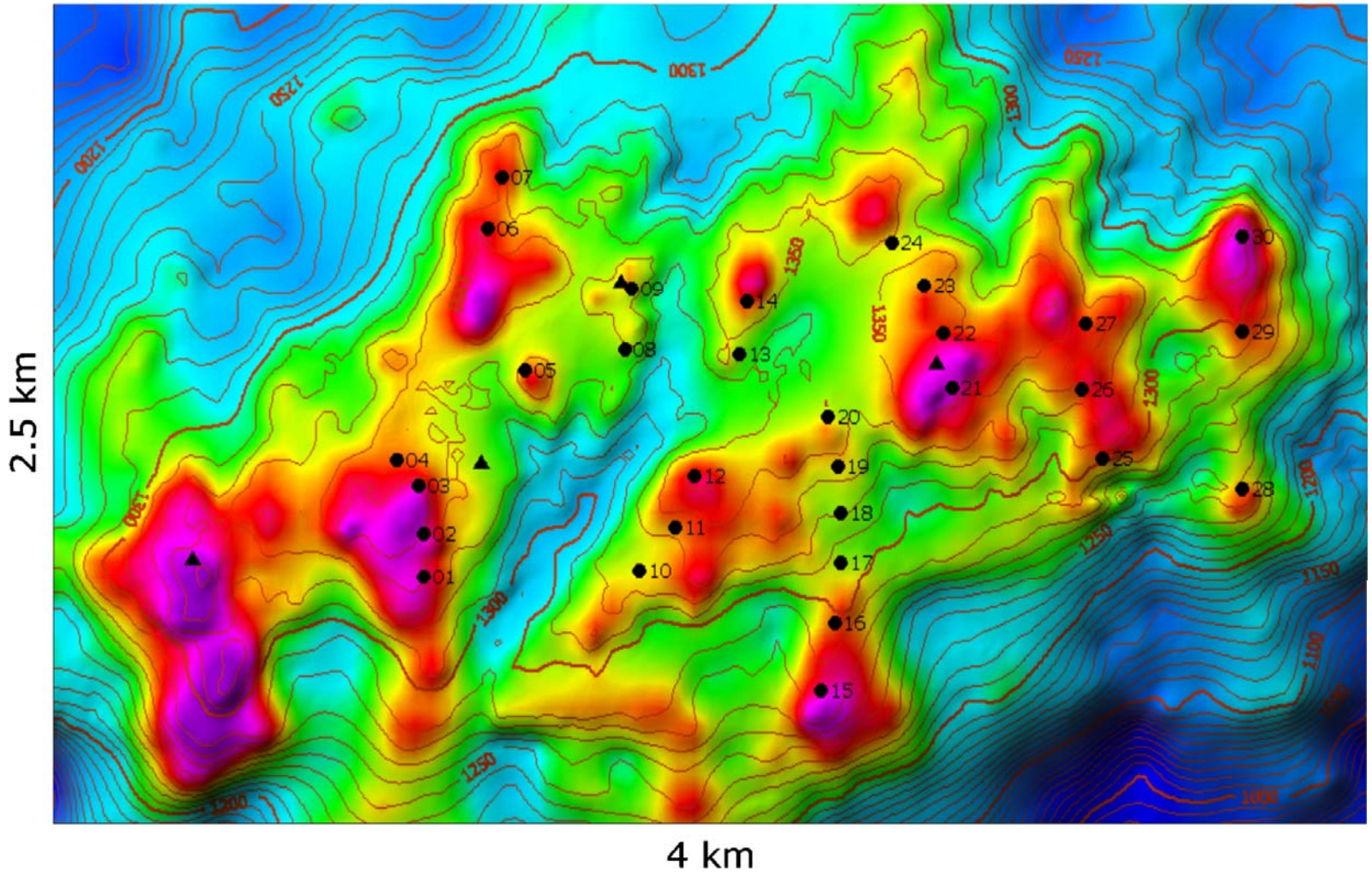
Comparison of Regional Wind Climates



Comparison of cross-predictions



Wind farm calculations



Key figures for three 20-MW wind farms

Turbine type	Gamesa G47	Nordex N62	Enercon E66
Rated power	30×660 kW	16×1300 kW	11×1800 kW
Hub height	50 m a.g.l.	69 m a.g.l.	67 m a.g.l.
Total net AEP	**57.7 GWh**	**56.8 GWh**	**58.3 GWh**
Range [GWh]	5.11-5.43	3.10-3.99	1.77-2.17
SRTM maps*	Δ = -0.9%	Δ = -0.4%	Δ = -1.7%
Total net AEP	**57.2 GWh**	**56.6 GWh**	**57.3 GWh**
Range [GWh]	5.17-5.44	3.19-4.07	1.76-2.18

* Details only added around the met. station – not the turbine sites!

SRTM maps for wind power use

- Pros
  - Overview of large-scale terrain features
  - Topographical setting of WAsP domain
  - Ideal for finding prospective wind farm sites
  - Ideal for various other planning purposes
  - WAsP orography maps in about an hour!
  - Digital Surface Model (DSM) rather than DEM (?)
  - Free of charge and easily accessible
- Cons
  - Accuracy not known in detail
  - Undefined grid point values (voids)
  - Erroneous grid point values (spikes and wells)
  - Shoreline not well defined

SRTM maps for WAsP use

- Elevation maps derived from 3 arc-sec SRTM data seem highly applicable for micro-scale modelling, provided
  - Voids are filled
  - Map is checked for errors
  - Spot heights/details are added!
  - Roughness information is added
  - Shoreline is taken from WVS or a standard topographical map
- More information is available from
  - http://www2.jpl.nasa.gov/srtm/ (SRTM home page)
  - ftp://e0mss21u.ecs.nasa.gov/srtm/ (SRTM ftp site)
  - “Satellite information for wind energy applications” by Nielsen *et al*. (2004). Risø-R-1479(EN), 56 pp.

SRTM bibliography

- Coltelli, M., *et al*. (1996). SIR-C/X-SAR multifrequency multipass interferometry: A new tool for geological interpretation. *Journal of Geophysical Research*, vol. 101, 23127-23148.

- Farr, T.G., and M. Kobrick (2000). Shuttle Radar Topography Mission produces a wealth of data. *Amer. Geophys. Union Eos,* v. 81, 583-585.

- Moreira, J., *et al*. (1995). X-SAR interferometry: First results. *IEEE Trans. Geosci. Remote Sensing*, vol. 33, no. 4, 950-956.

- Rabus, B., *et al*. (2003). The shuttle radar topography mission – a new class of digital elevation models acquired by spaceborne radar. *Photogramm. Rem. Sens*., v. 57, 241-262.

- Werner, M. (2001). Shuttle Radar Topography Mission (SRTM). Mission overview, *J. Telecom. (Frequenz)*, v. 55, 75-79.